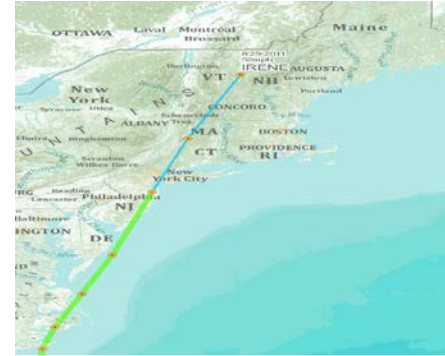


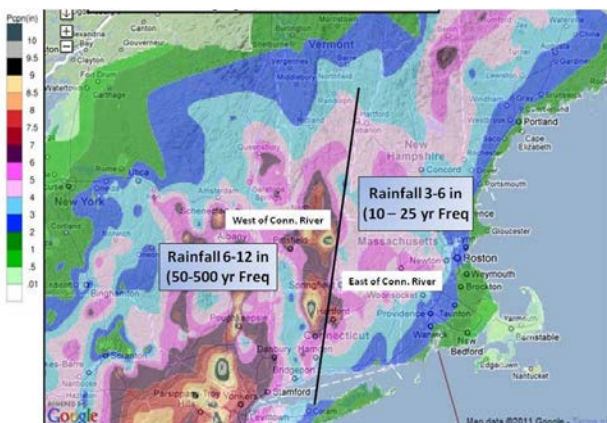
Tropical Storm Irene, August 2011

1. **General.** As Hurricane Irene travelled up the east coast of the United States during the week of 22 August, NAE began preparing for the storm. In an effort to have 100% of flood storage available, all Corps reservoirs were lowered to normal levels, and a few were lowered to below normal. In addition all hurricane barriers were tested and found to be fully operational. On 28 August, Irene made landfall as a Tropical Storm over western Long Island, and followed a path through western Connecticut and to the west of the Connecticut River through Massachusetts and Vermont, ultimately losing its tropical characteristics as it accelerated into Canada by August 29th.



2. **Impact.** As the storm hit the New England region, the heaviest rainfall occurred to the west of the storm track and the highest winds, and tidal surges, were to the east.

a. **Tidal Surge .** On the morning of 28 August, a tide surge of approximately 4.3 ft occurred along Long Island Sound at the Stamford Hurricane Barrier in Stamford, Connecticut. The surge occurred coincident with high tide, resulting in a tide level of 9.6 ft-NGVD. This was the third highest tide level since the barrier was constructed in 1969. The barrier was operated and pumps activated due to 7 inches of rain that fell in the harbor's watershed. This operation held the harbor stage to a non-damaging level of less than 4 ft. At the New Bedford Barrier in Buzzards Bay, MA and Fox Point Barrier in Narragansett Bay, RI, the maximum tidal surges experienced were 3.9 ft and 5.0 ft, respectively. At these locations, the maximum surges did not occur coincident with the high tide and maximum tide levels reached were 5.6 ft-NGVD at New Bedford and 8.4 ft-MLLW at Fox Point. The surges at the time of high tide were only 2.6 ft and 3.0 ft respectively. Both barriers were operated and harbor water levels were kept to non-damaging levels.



Tropical Storm Irene Precipitation
(27-28 August 2011)

b. **Rainfall –** The rainfall distribution occurred as forecasted within watersheds along the track, with areas to the west of the track experiencing the greatest rainfall, and those to the east the least. Rainfall totals of 6 to 12 inches occurred over the watersheds in western New England including the Naugatuck River Basin in Connecticut and the Connecticut River Basin in Connecticut, Massachusetts,

and Vermont. Eastern watersheds including the Thames, Blackstone, and Merrimack River Basins experienced approximately 3 to 6 inches of rain. Rainfall totals for each of the Corps' dams and corresponding peak pool levels are presented below.

c. Flooding . Significant flood runoff occurred in the Naugatuck and Connecticut River Basins, where some areas, especially in western Massachusetts and Vermont, experienced record flood levels. All other river basins experienced flood conditions, but did not approach significant or record levels. Total damages prevented by Corps dams, hurricane barriers, and local flood protection projects was about \$1.0 Billion, with 78% attributed to regulated operations at Corps dams and hurricane barriers, and 22% attributed to local flood protection projects.

(1) Naugatuck River Basin. Approximately 6 to near 10 inches of rain occurred in an 18 hour period, as a result of Tropical Storm Irene. This high volume of rainfall, over such a short duration, lead to widespread, significant flooding in the Naugatuck River Basin, and on the main stem Housatonic River on 28 August. Along the Naugatuck River, all index stations rose 3 to 4 ft over flood stage. Had Corps dams not held back significant inflows, river levels would have resulted in levels of 5 to 6 ft over flood stage. Some flood conditions along the Housatonic River in Massachusetts and Connecticut were very significant as the river level at Stevenson, CT crested at 20.9 ft, only 3.8 ft lower than the October 1955 flood of record. Corps dams in the Naugatuck River Basin typically utilized 30-70% of flood storage. Two Corps dams experienced pools of record: Black Rock Dam, peak pool of 94.8 ft or 69% of flood storage, and the nearby Northfield Brook Dam having a peak pool of 78.5 ft or 59% of flood storage. A summary of river stage information showing the effectiveness of Corps dams is presented below.

Effect of Corps Dams at Selective River Stations						
Location	D.A. (sq.mi)	Flood Flow(cfs)	Observed Flow (cfs)	Natural Peak (cfs)	Reduction Flow (%)	Reduction Stage (ft)
Naugatuck River Basin						
Naugatuck R @Waterbury, CT	174	5,280	16,400	37,000	56	5.2
Naugatuck R @Beacon Falls, CT	259	9,950	20,300	40,200	50	4.3

(2) Connecticut River Basin. Approximately 6 to over 11 inches of rainfall occurred in the Connecticut River Basin, with the highest amounts west of the main stem Connecticut River. The rainfall occurred during a 12-18 hour period, with some totals exceeding the 100 year rainfall frequency, and approaching a 500 year frequency. The highest totals occurred in the headwaters of the Westfield watershed in Massachusetts and in the higher elevations of Vermont. Significant to record flooding occurred throughout the entire basin, bringing river levels 7 to 8 ft above flood stage in the Westfield watershed where a new record

peak stage of 17.6 ft was experienced on the West Branch Westfield River at Huntington, MA. This is the highest river stage recorded in the station's 78 year period of record and equivalent to well over a 100 year frequency event. Had Knightville and Littleville Dams not held back significant inflows, river levels at the Westfield River at Westfield would have risen another 10 ft higher; which would have been about 4 ft lower than the August 1955 flood of record for this station. Similar conditions occurred on many uncontrolled tributaries in Vermont, where river levels rose to 8-10 ft over flood stage. In many places, these levels were either record levels or the highest since the historic flood of November 1927. Along the Deerfield River at Deerfield, whose headwaters originate in Vermont, the river level crested at 23.8 ft. This is the highest stage recorded in its 70 year period of record. Photos depicting the magnitude of the flood and the destruction it caused are shown below.



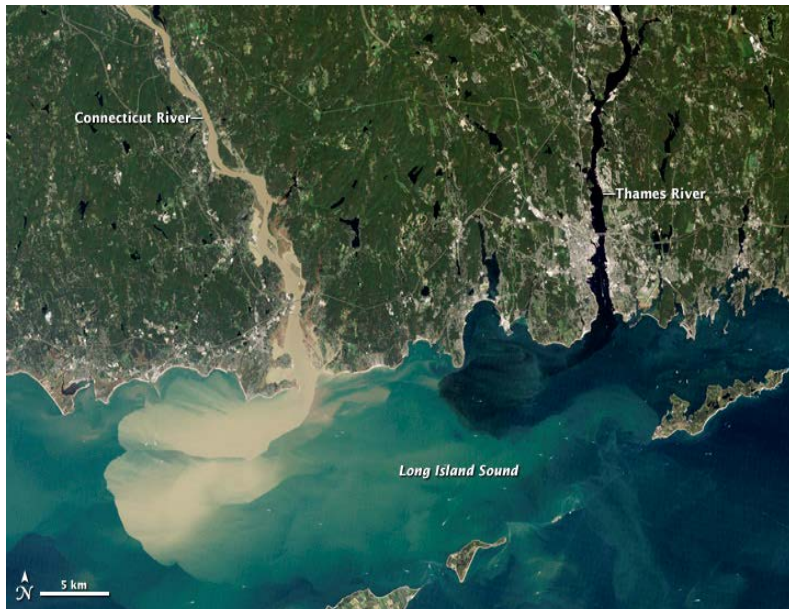
Highway damage in Vermont



Structural damage in Vermont



Suspended sediment collected at Townshend Dam, Vermont



Sediment carried by flood waters of the Connecticut River into Long Island Sound

Suspended sediment caused by Irene flowed from the watersheds in Vermont, New Hampshire and Massachusetts, discharging into Long Island Sound. Since Irene occurred just prior to harvest season, it may have long term impacts on the local farming industry. In the above photograph, it can be noted that the Thames River, located to the east of the track of Irene, was running clear, with little sediment transport visible on the satellite image.

Corps dams in the Connecticut River Basin typically utilized 20 -80% of flood storage capacity. One Corps dam experienced its pool of record: Mad River Dam had a peak pool of 80.6 ft or 31% of flood storage. A summary of river stage information showing effectiveness of Corps dams is presented below.

Effect of Corps Reservoirs at Selective River Index Stations						
Location	D.A. (sq.mi)	Flood Flow(cfs)	Observed Flow (cfs)	Natural Peak (cfs)	Reduction Flow (%)	Reduction Stage (ft)
Connecticut River Basin						
Westfield R @ Westfield, MA	497	11,300	17,000	57,000	70	10
Connecticut R @ Montague, MA	7,865	89,700	127,000	161,000	21	4.7

(3) Thames, Blackstone, and Merrimack River Basins. During Irene, rainfall totals of 3-6 inches typically occurred, bringing rivers to near flood stage. Although there were some rainfall totals in isolated areas approaching 8-9 inches, especially in the Blackstone River Basin, it was not uniformly distributed and therefore did not produce significant flooding. The main stem of the Blackstone River at Woonsocket, RI rose to flood stage, but it did not exceed the start of damage stage. River levels in the Thames River Basin did not exceed flood stage nor did river levels in the Merrimack River Basin. Had Corps dams not stored flood waters in these basins, river levels downstream would have rose an additional 3-6 ft, producing damaging flood levels at many locations. Corps dams in the Blackstone, Thames and Merrimack River Basins utilized 10-40% of their flood storage. A summary of river stage information showing effectiveness of Corps dams is presented below.

Effect of Corps Reservoirs at Selective River Index Stations						
Location	D.A. (sq.mi)	Flood Flow(cfs)	Observed Flow (cfs)	Natural Peak (cfs)	Reduction Flow (%)	Reduction Stage (ft)
Blackstone River Basin						
Blackstone R @ Woonsocket, RI	416	6,670	6,670	7,325	9	0.5
Thames River Basin						
Quinebaug R @ Putnam, CT	331	4,991	3,260	10,137	68	6.7
Merrimack River Basin						
Merrimack R @ FranklinJct,NH	1,507	18,180	17,680	47,430	63	11.5

3. Damages Prevented. As a result of Tropical Storm Irene, the majority of New England's widespread damage to roads, bridges and property was along uncontrolled rivers where Corps dams have no influence. Corps dams and hurricane barriers, as well as Corps constructed local protection projects, were effective in reducing damages for damage zones they were designed to protect. Total damages prevented during this event were approximately \$1 Billion. Of the

cumulative damages prevented, 78% were attributed to NAE dams and barriers, and 22% to local protection projects. Damages prevented as a result of the Stamford and New Bedford Hurricane Barriers during the tide cycle on the morning of 28 August were \$5.8 Million and \$355,000, respectively. There were no damages prevented from the operation of Fox Point barrier as the ocean did not reach damaging levels. A distribution by river basin, as well as by state, is presented below.

Damages Prevented by Basins and Barriers			
River Basin	Dams	LPP	Total
Connecticut	375,046,000	165,332,000	540,378,000
Naugatuck	360,378,000	47,648,000	408,026,000
Thames	41,269,000	0	41,269,000
Merrimack	4,512,000	848,000	5,360,000
Blackstone	8,055,000	11,118,000	19,173,000
Hurricane Barriers			6,224,000
Total	\$789,260,000	\$224,946,000	\$1,020,430,000

Damages Prevented by State				
State	Dams	LPP	Hurricane Barriers	Total
Vermont	30,667,000	0	N/A	30,667,000
New Hampshire	9,256,800	848,000	N/A	10,104,800
Massachusetts	256,815,800	61,940,000	355,000	319,110,800
Connecticut	486,688,400	162,158,000	5,869,000	654,715,400
Rhode Island	5,832,000	0	0	5,832,000
Total	\$789,260,000	\$224,946,000	\$6,224,000	\$1,020,430,000